Insulation for Sustainable Cooling Systems

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MAKING A DIFFERENCE AROUND THE WORLD

GRIHA
THE 10TH GRIHA SUMMIT 2018
December 11th–13th, 2018 | New Delhi
Fostering Partnerships for Sustainable Habitat

// AGENDA

- Need for Sustainable Cooling Systems
- Role of Insulation
- Types of Insulation
- Choosing the Right Insulation
- Technical Parameters
- Thickness Selection of Insulation
- Effect of External Surface Coefficient

Introduction

Sustainable Air Conditioning

The increasing population, technological advancements, and materialistic living standards have significantly increased the energy demand for cooling devices in last few decades.

15% of world's total energy is consumed by air conditioning systems

Energy is wasted during the process of **Overcooling and Reheating**

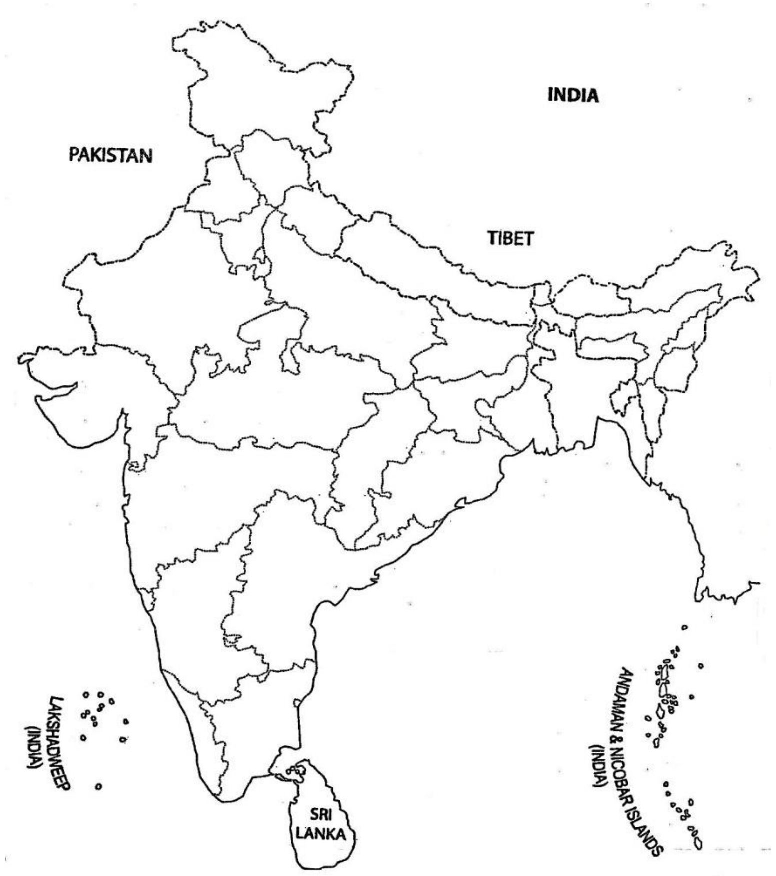
10% of the CO_2 emissions are from Coling Systems

Not properly insulated Systems causes rise in growth of **Bacteria**

Introduction

Need for Sustainable Air Conditioning

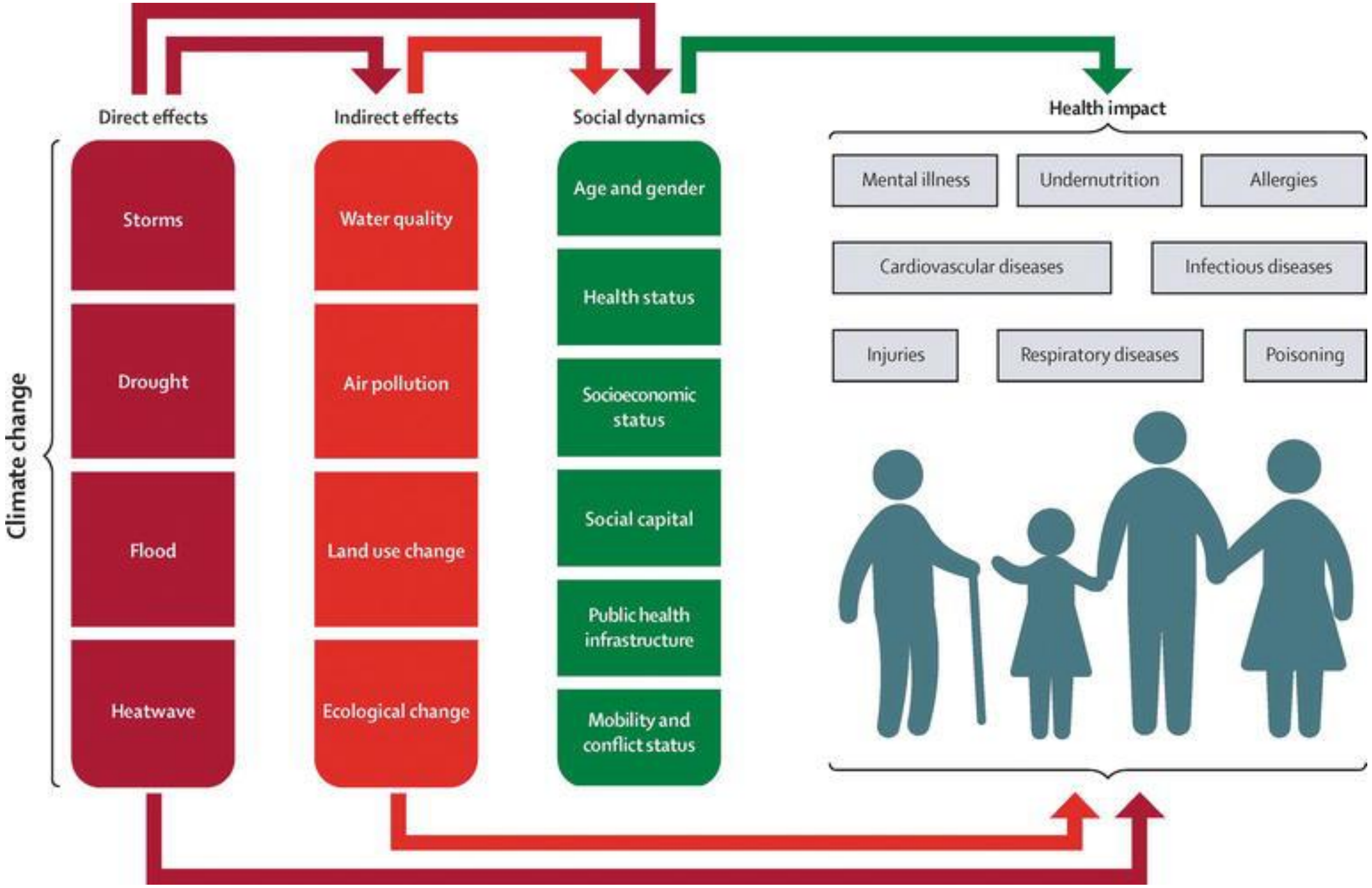
India has the least access to cooling systems which is reflected by its low per capita levels of energy consumption for space cooling at 69 KWh as compared to world average of 272 KWh.

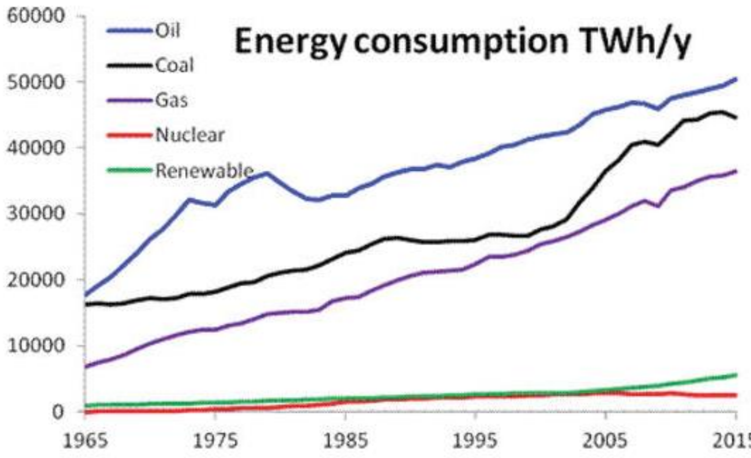


- Growing Market for Cooling Systems.
- Means more Energy Consumption year on year on cooling systems
- All the more need to adopt sustainable cooling systems.

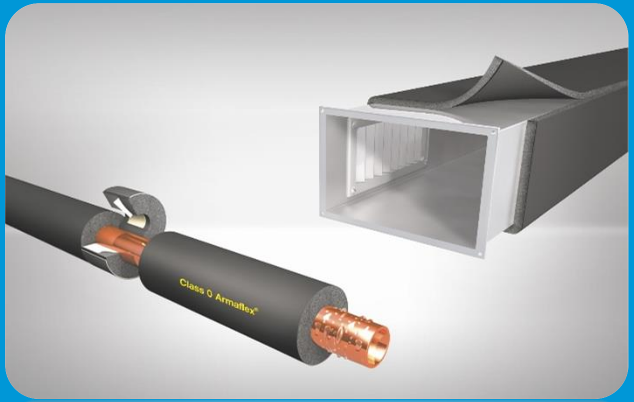
Need of renewable based technology

Sustainable Air Conditioning



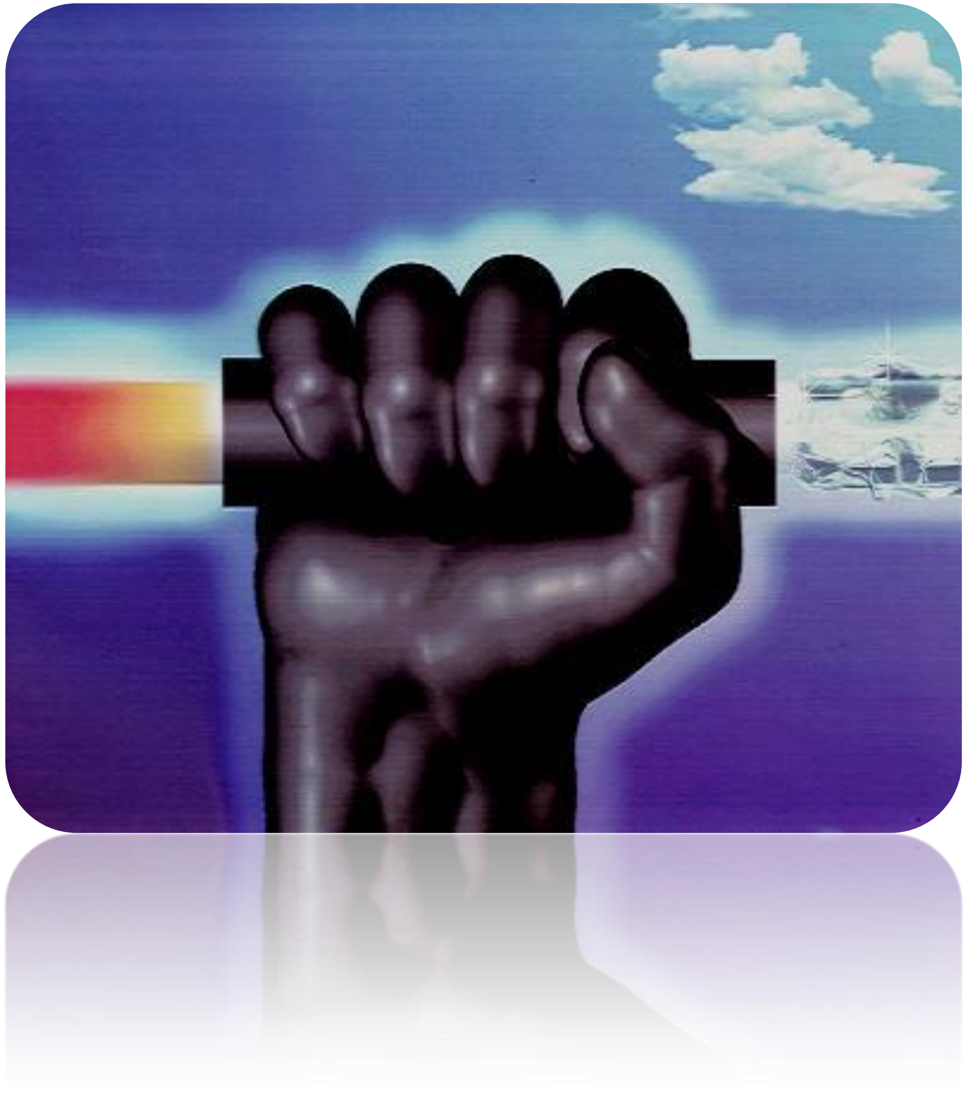


The increasing use of fossil fuels not only causing fast depletion of energy sources but also causes emitting harmful gases which directly affects the human life.



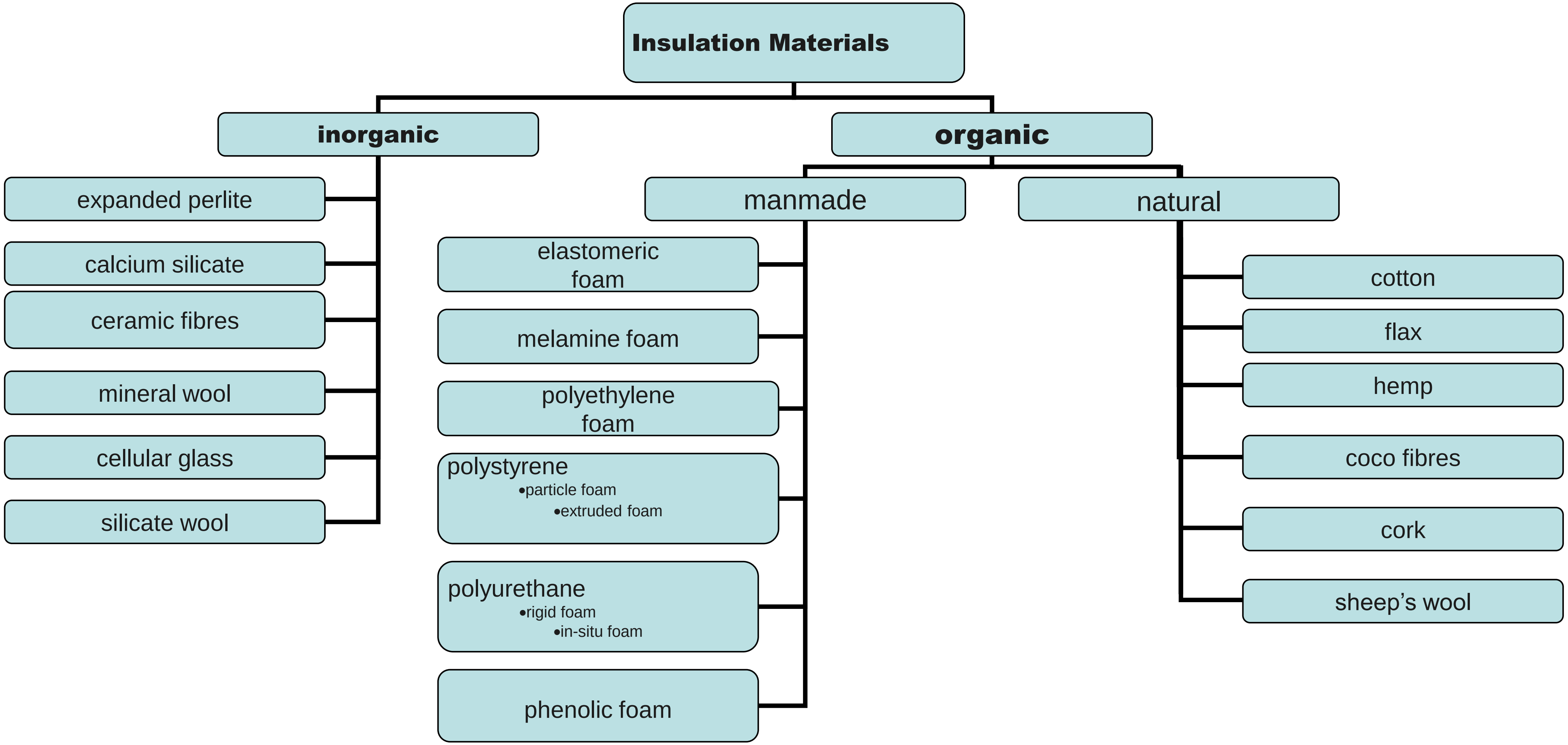

INSULATION

INSULATION FOR SUSTAINABLE COOLING SYSTEMS

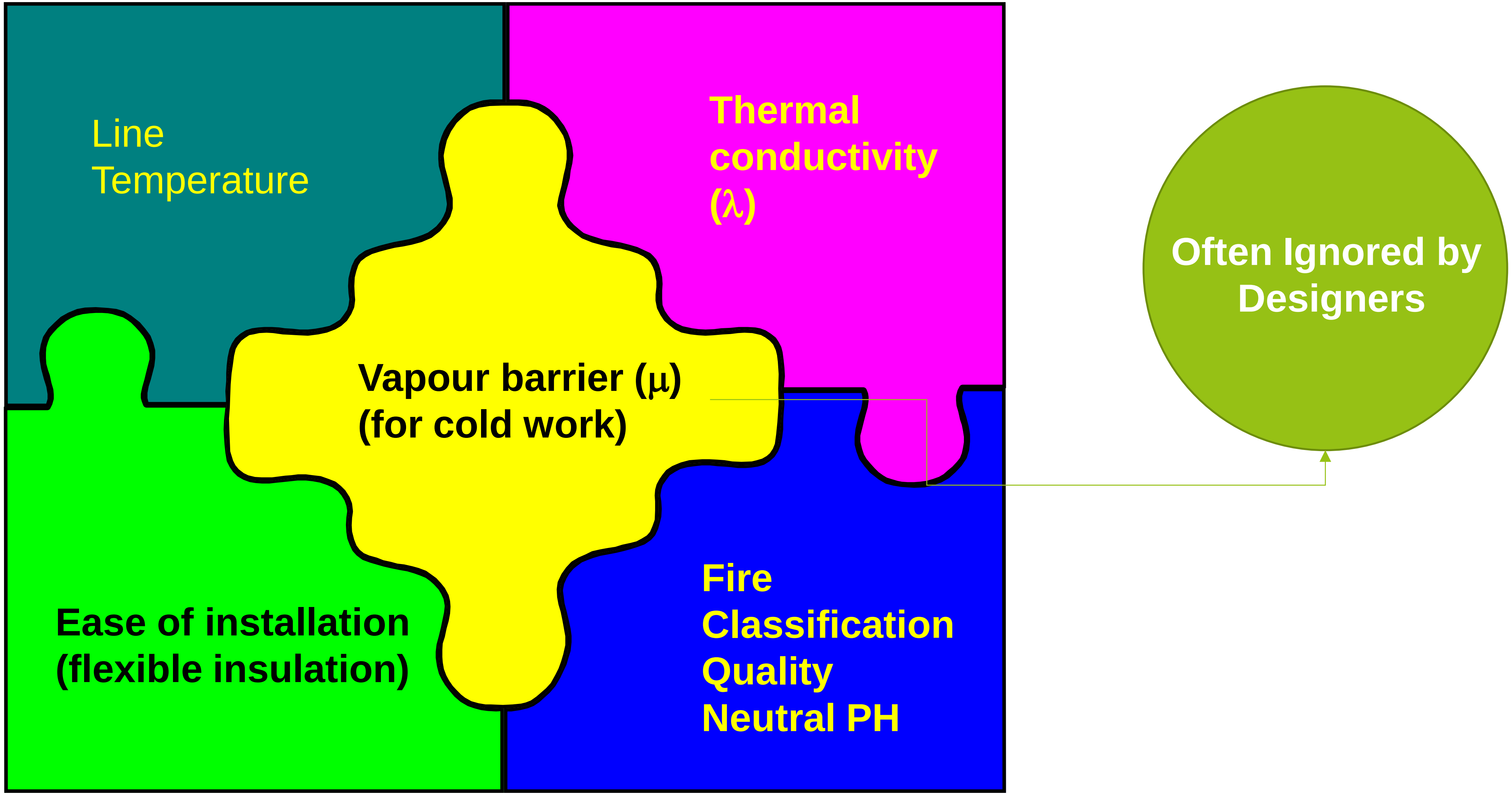


- Insulation – an integral part of all cooling systems.
- Responsible for Energy Efficiency in the cooling systems.
- Right Insulation would mean more efficient cooling systems.
- Insulation should be chosen to ensure energy savings for the life cycle of the insulation – stable thermal K values rather than the initial values and also eco friendly options should be chosen.

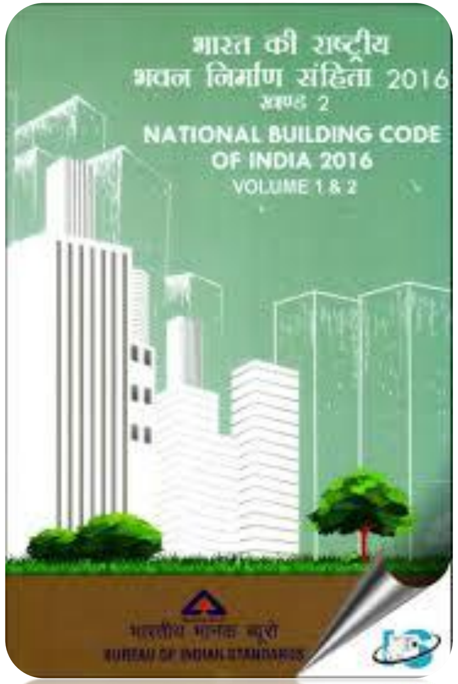
INSULATION MATERIAL GENERICS



CHOICE OF THERMAL INSULATION



FELXIBLE ELASTOMERIC FOAMS



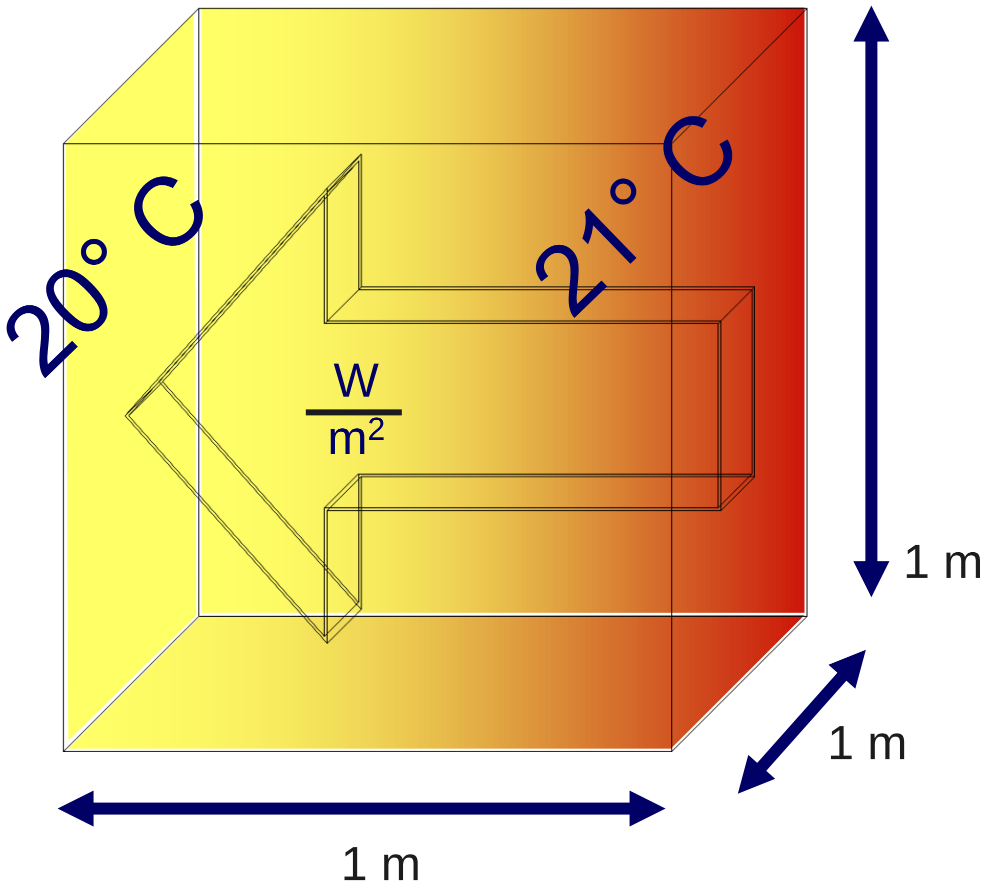
- NBC 2016 recommends the use of Fibre Glass, PUF, EPS and **Flexible Elastomeric Foams** for Insulation of air-conditioning systems.

  1. Ducting Insulation: as per NBC 2016 Part 8 - Building Services - HVAC Item No. 12.1.9.1
  2. Chilled Water Piping: as per NBC 2016 Part 8 - Building Services - HVAC Item No. 12.1.9.5
  3. Acoustic Insulation: as per NBC 2016 Part 8 - Building Services - HVAC Item No. 12.1.9.3

- Flexible Elastomeric Foams are Rubber Based Foams based on synthetic rubber.

- In the HVAC Industry, Nitrile Butadiene Rubber (commonly known as Nitrile Rubber) based foams are widely used.

THERMAL PROPERTIES OF INSULATION



Thermal conductivity λ [W/(m·K)]

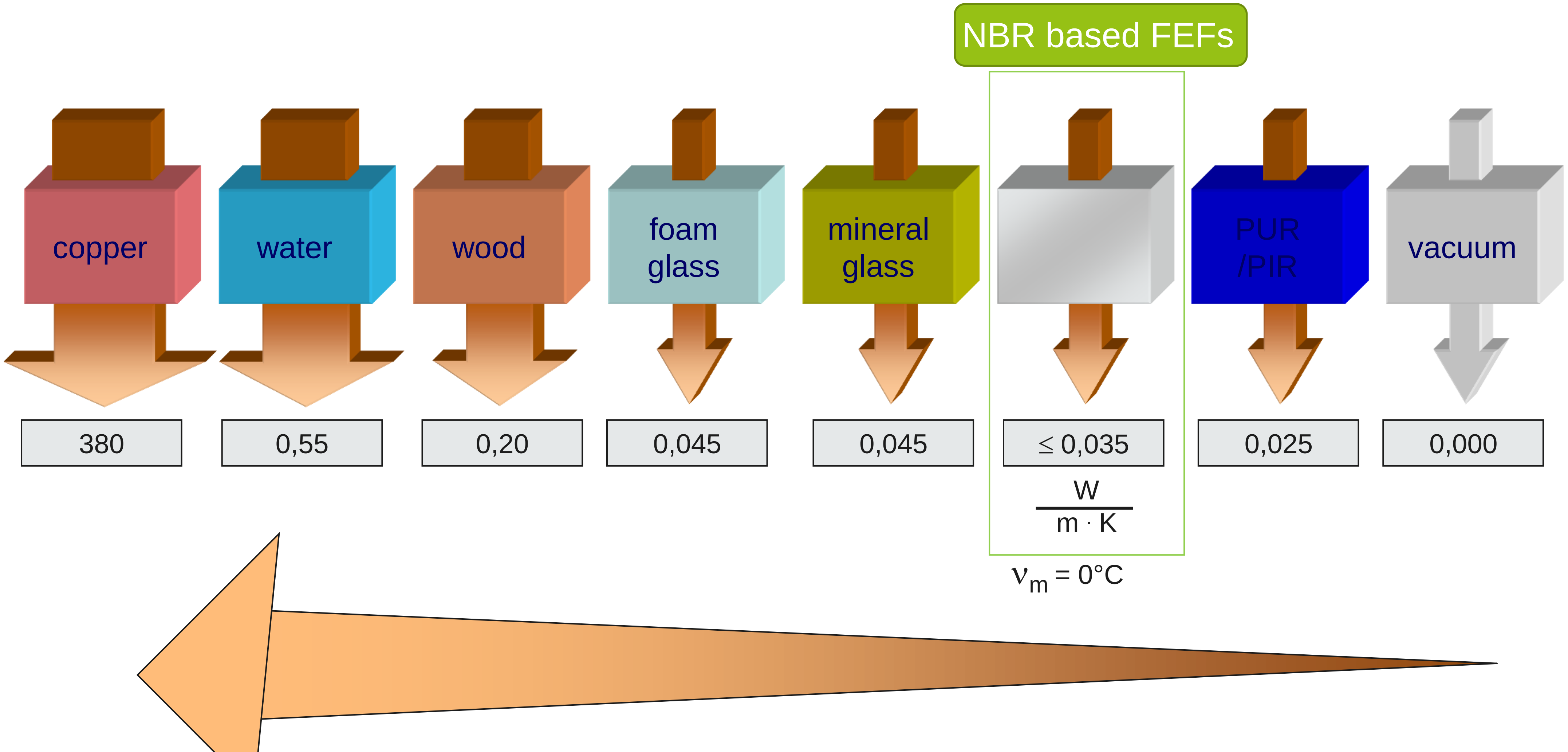
Example:

1. For Nitrile Rubber based FEFs at mean temp.0°C

$$\lambda \leq 0{,}035 \text{ W/(m·K)}$$

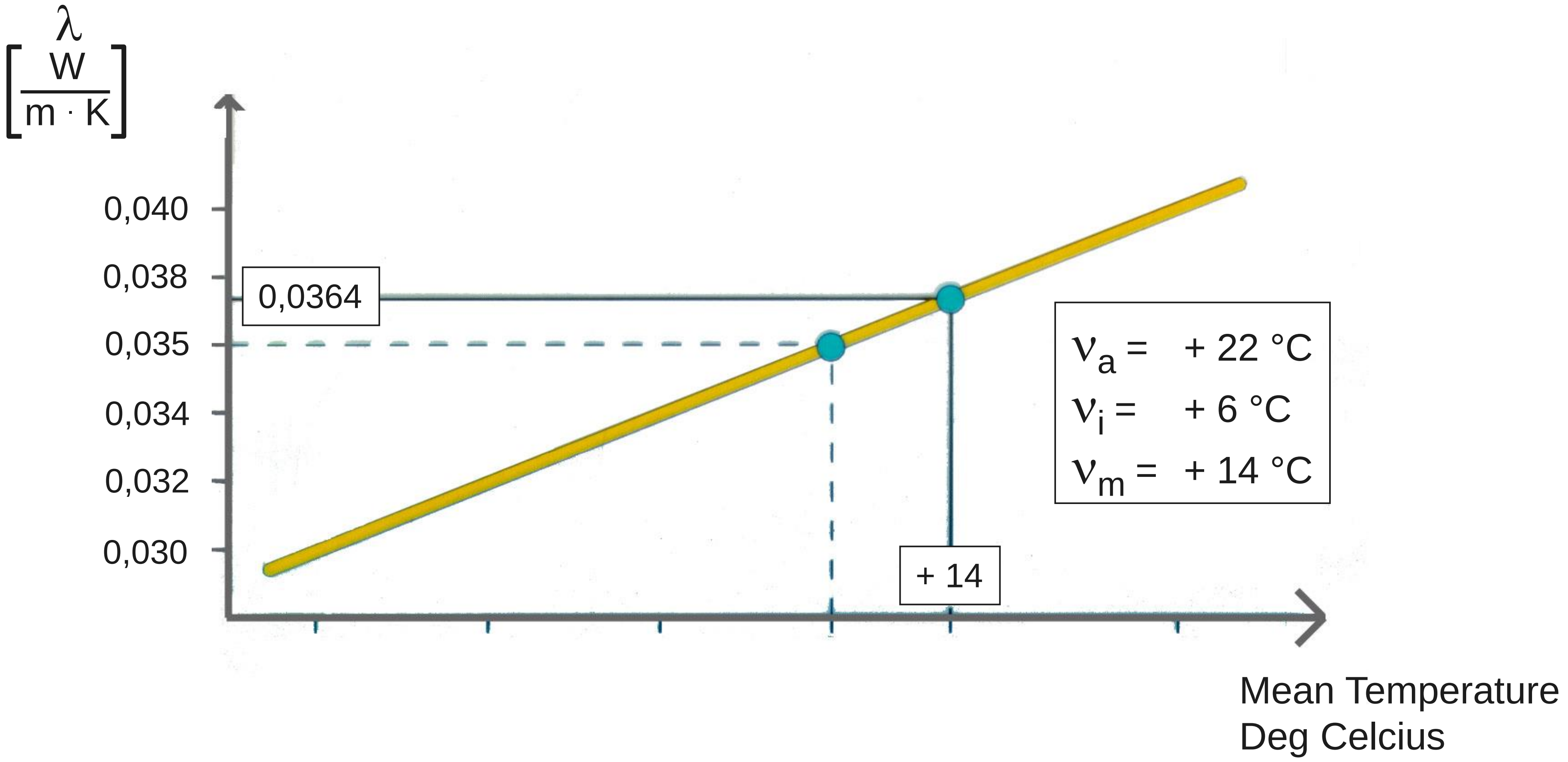
2. For air λ = 0,024 W/(m·K)

SMALLER THE λ - VALUE BETTER THE INSULATION



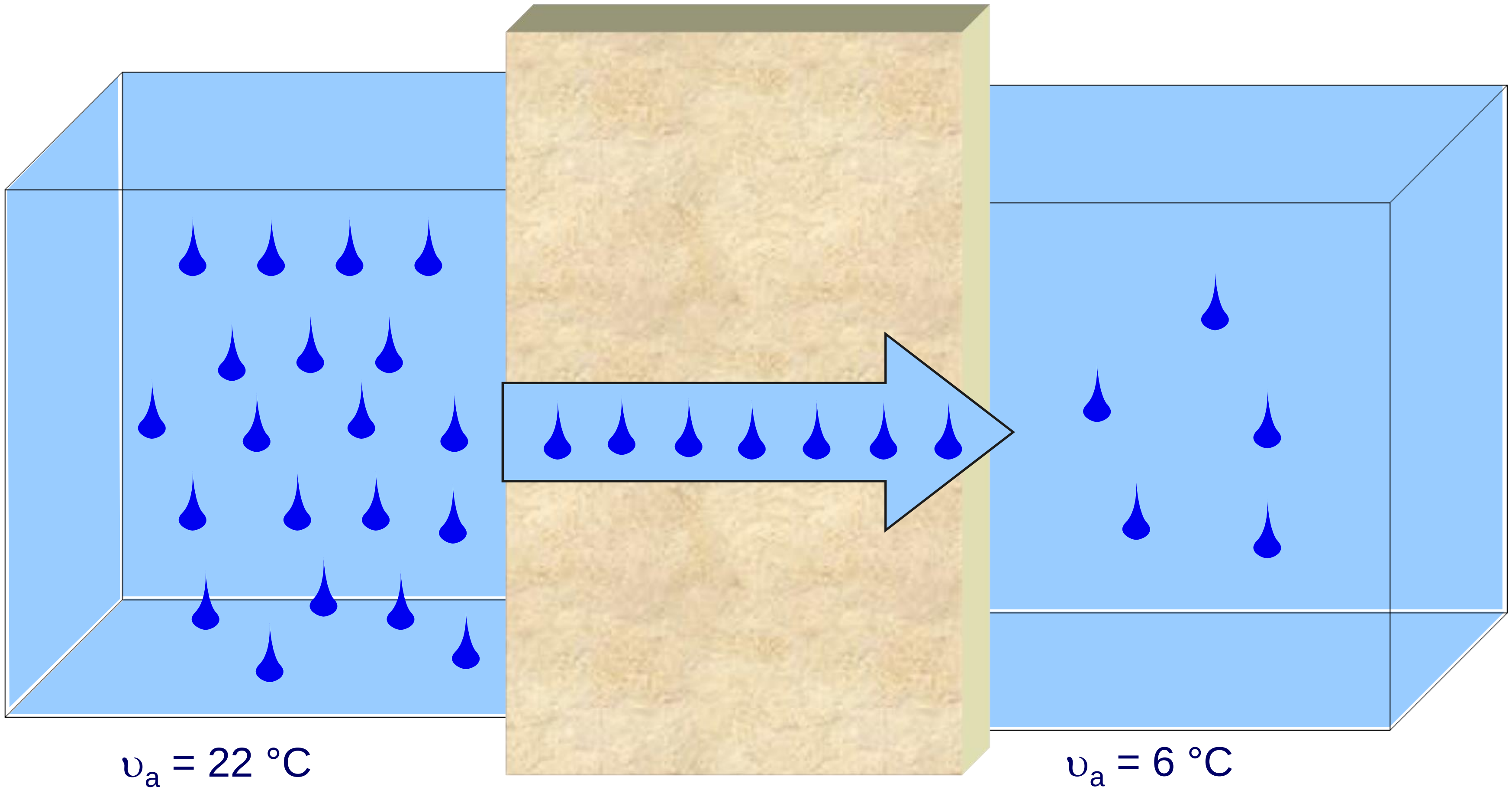
λ property of the material, is independent of insulation thickness

THERMAL CONDUCTIVITY OF CLASS O ARMAFLEX IN RELATION TO THE MEAN TEMPERATURE



WATER VAPOUR TRANSMISSION / WATER VAPOUR PERMEABILITY

THE DRIVING FORCE BEHIND WATER VAPOUR DIFFUSION



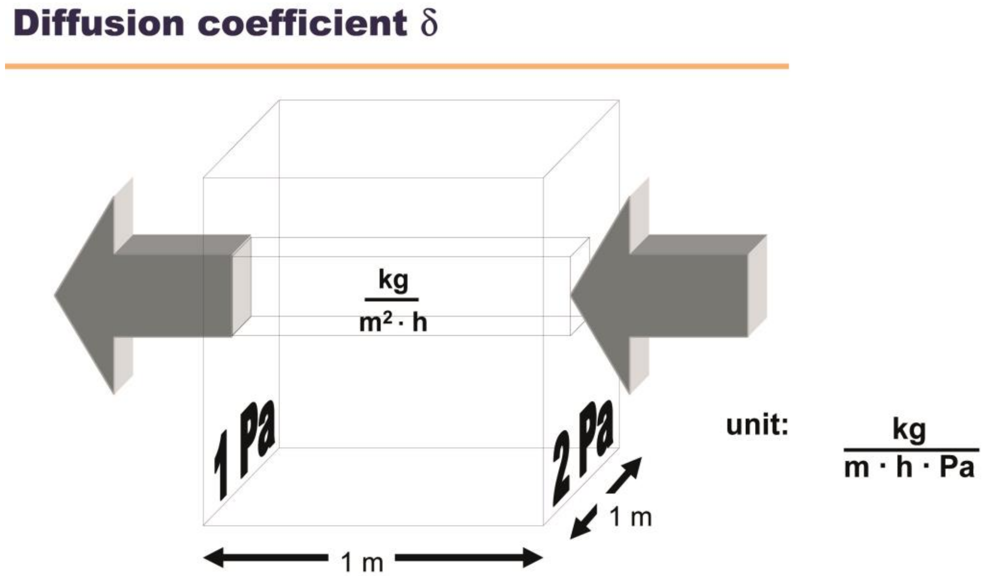
$\upsilon_a = 22\ °C$
$\varphi\ = 85\ \%$
$P_D = 22.5\ hPa$

$\upsilon_a = 6\ °C$
$\varphi\ = 100\%$
$P_D = 9.3\ hPa$

THE WATER VAPOUR DIFFUSION COEFFICIENT ‘δ’

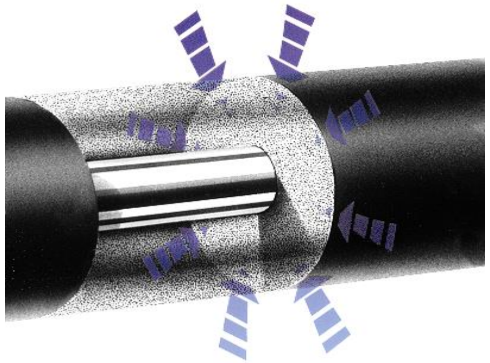
- Generally known as **Water Vapour Permeability**

- *“The amount of water vapour (Kg) which diffuses through a unit layer of material (of 1 meter thickness) and through a unit area (of 1 square meter), at a unit partial pressure difference (of 1 Pa), in unit time (of 1 hour)”*



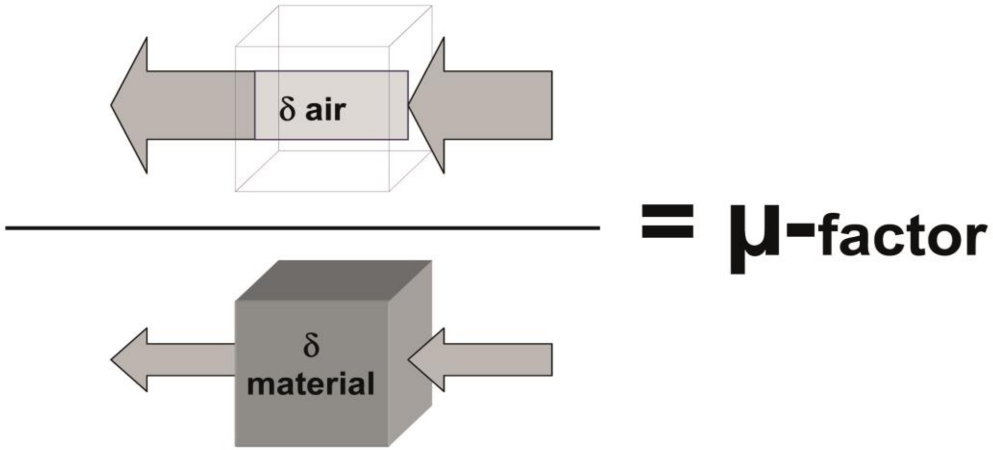
The lower the value, better is the insulation material

THE WATER VAPOUR DIFFUSION RESISTANCE FACTOR (μ)



"It is a dimensionless number describing how many times better a material is at resisting the diffusion of water vapour, compared with an equivalent thickness of air"

Resistance to water vapour diffusion factor μ



The Higher the value better is the insulation material

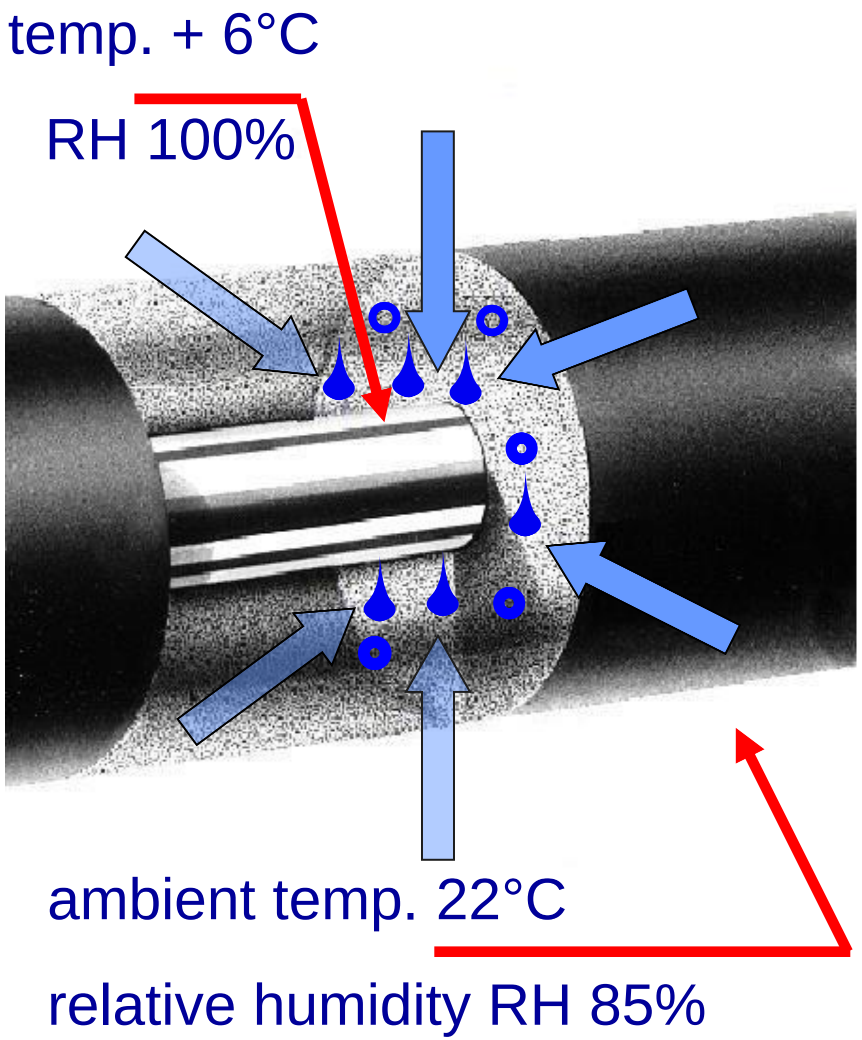
THE WATER VAPOUR DIFFUSION RESISTANCE FACTOR (μ)

There is pressure difference of water vapour between ambient air and closed cell structure of insulation.

There is pressure difference of water vapour between ambient air and closed cell structure of insulation.

For poor quality material (low μ value) insulation will get wet

Therefore one should apply high quality insulation materials i.e. with high value of water vapour diffusion resistance factor μ



Why is it Important to have **High Vapour Water Diffusion Resistance Coefficient (μ)** in the Insulation Material?

WATER VAPOUR SHOULD NOT PENETRATE THE INSULATION SYSTEM FOR THE FOLLOWING REASONS

- In the insulation material they reduce the insulation effect considerably

- because **water conducts** heat around **20 times higher** than **static air** [λ(air) $\approx$ 0.025 W/(m · K); λ (water) $\approx$ 0.6 W/(m · K)]

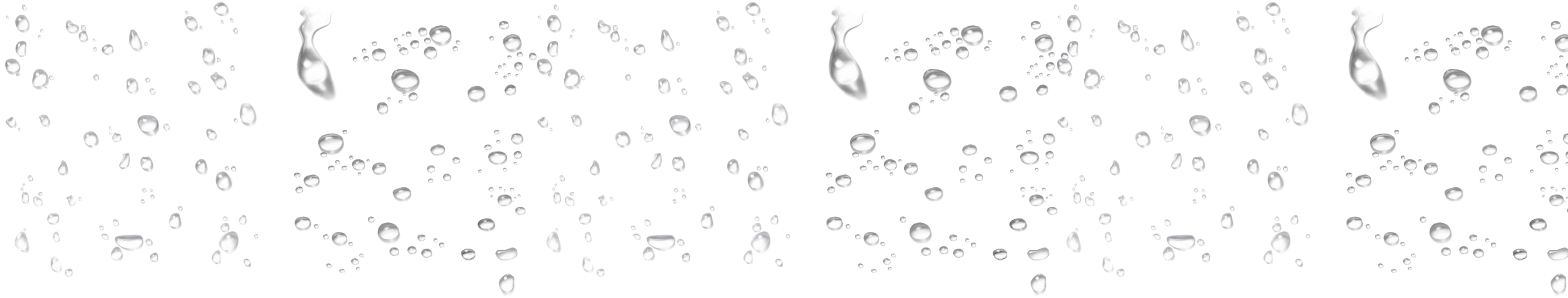
- The thermal conductivity of **ice** is around **100 times higher** than **static air.**

- This not only leads to **higher** energy losses, but in certain circumstances also means that the **insulation thickness determined in the dry state is no longer sufficient**. This in turn results in **condensation formation on the surface of the insulation material.**

WATER VAPOUR SHOULD NOT PENETRATE THE INSULATION SYSTEM FOR THE FOLLOWING REASONS

- **Water** can cause **corrosion** on insulated pipes and on the **inside of any metal jackets**. In the worst case this “**creeping**” **corrosion** can mean that the whole **refrigerating plant has to be replaced.**

- It is also important not to **underestimate** the **substantial weight gain due to water and ice**, which can lead to **static problems – especially in combination with the corrosion processes**

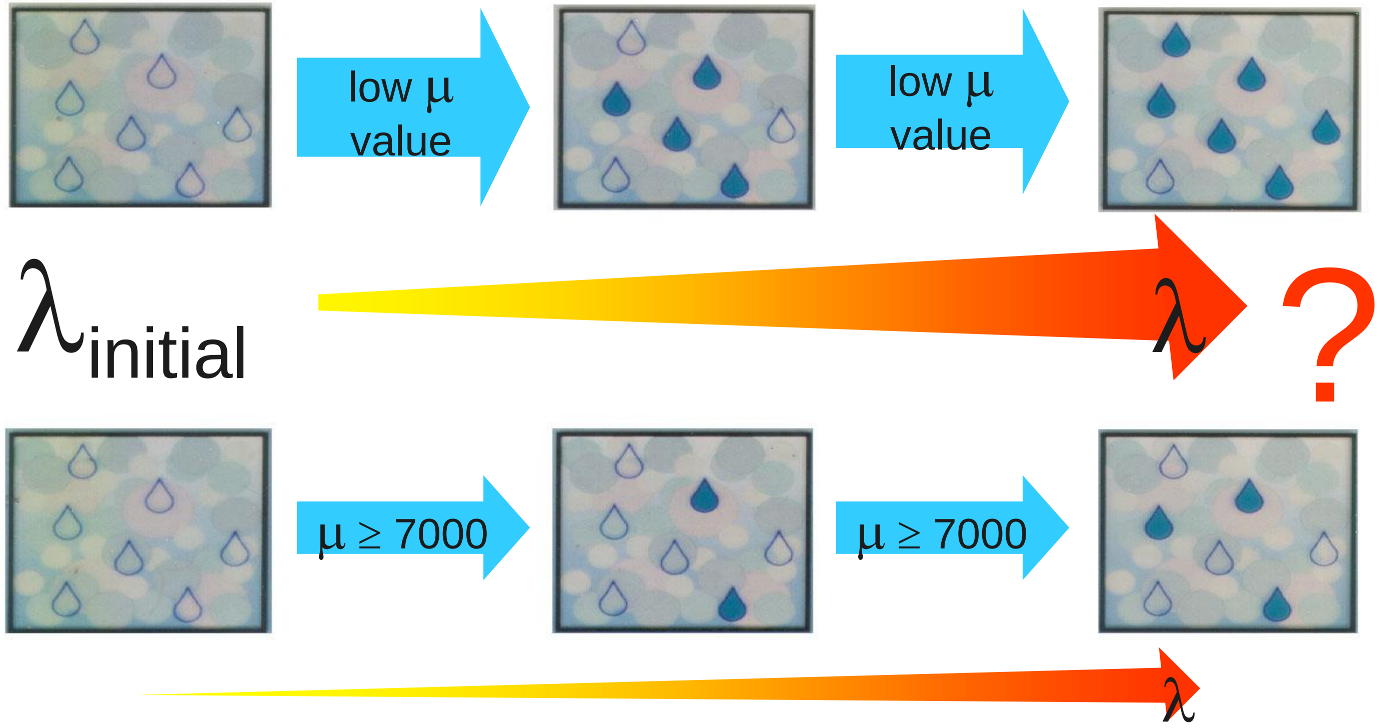


EFFECT OF WATER VAPOUR PERMEABILITY

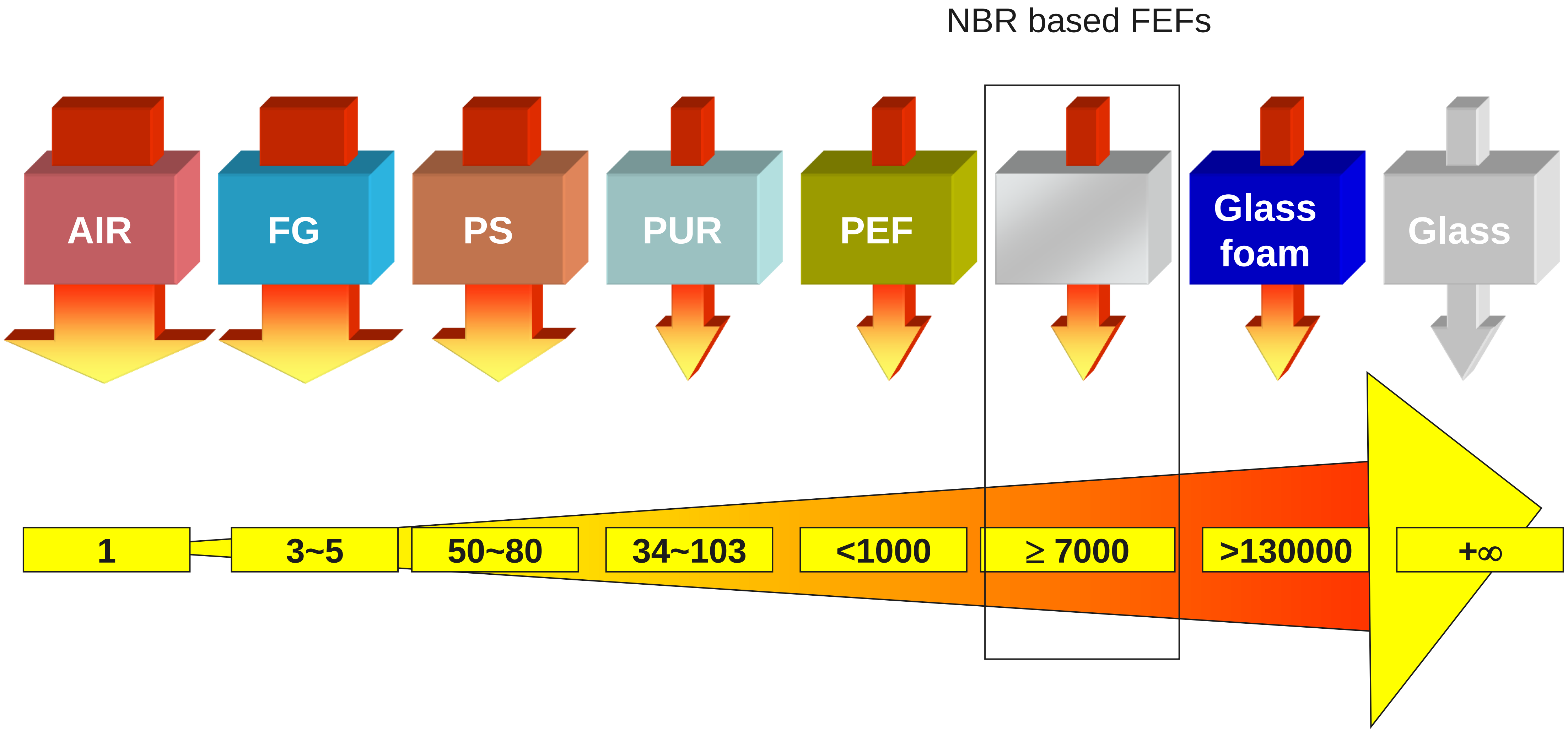
Examples of corroded pipe under a foil faced based insulation

EFFECT OF WATER VAPOR INGRESS ON THERMAL CONDUCTIVITY 'λ'

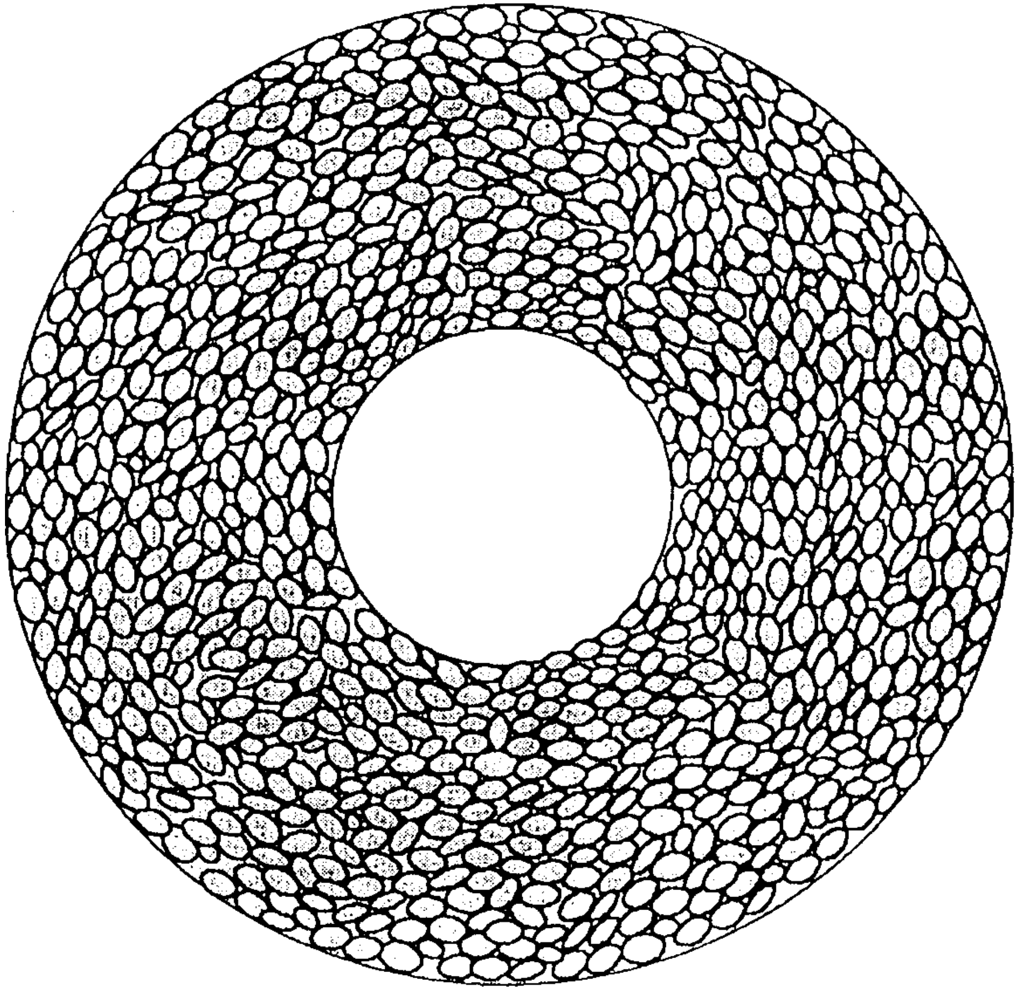
Every 1% by volume increase in moisture of the insulation yields a 4 – 8 % increase in thermal conductivity



μ-FACTOR OF TYPICAL INSULATION MATERIAL

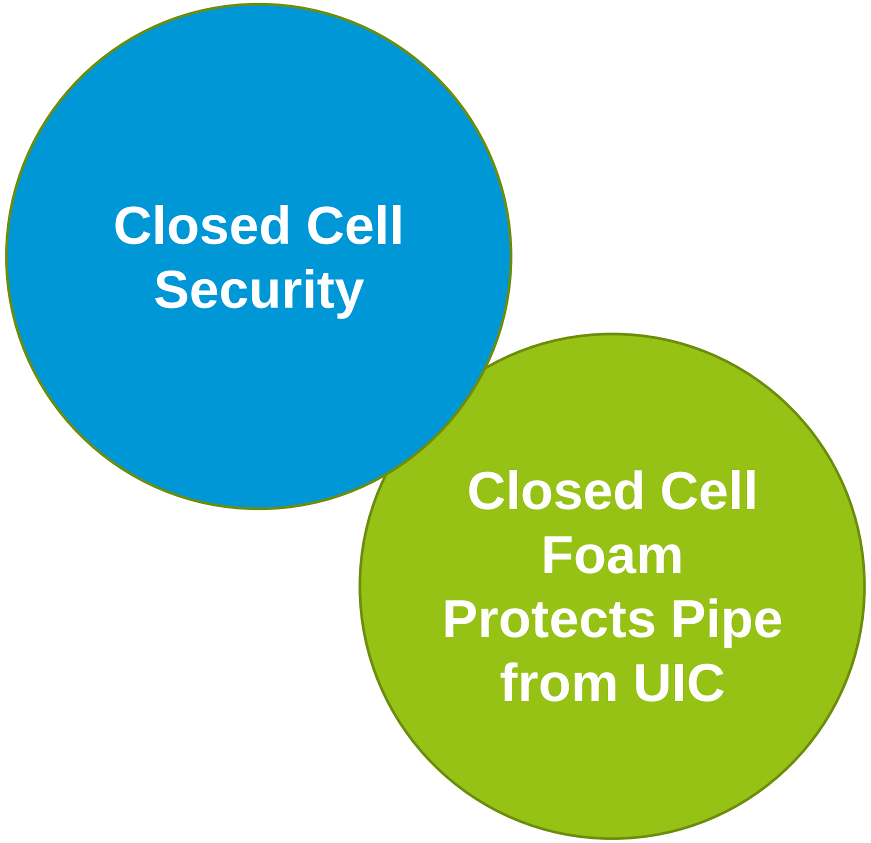


HIGH μ-FACTOR – CLOSED CELL STRUCTURE OF FEFs



Armaflex insulation materials have a closed cell structure

EFFECT OF HIGH μ-FACTOR OF TYPICAL INSULATION MATERIAL



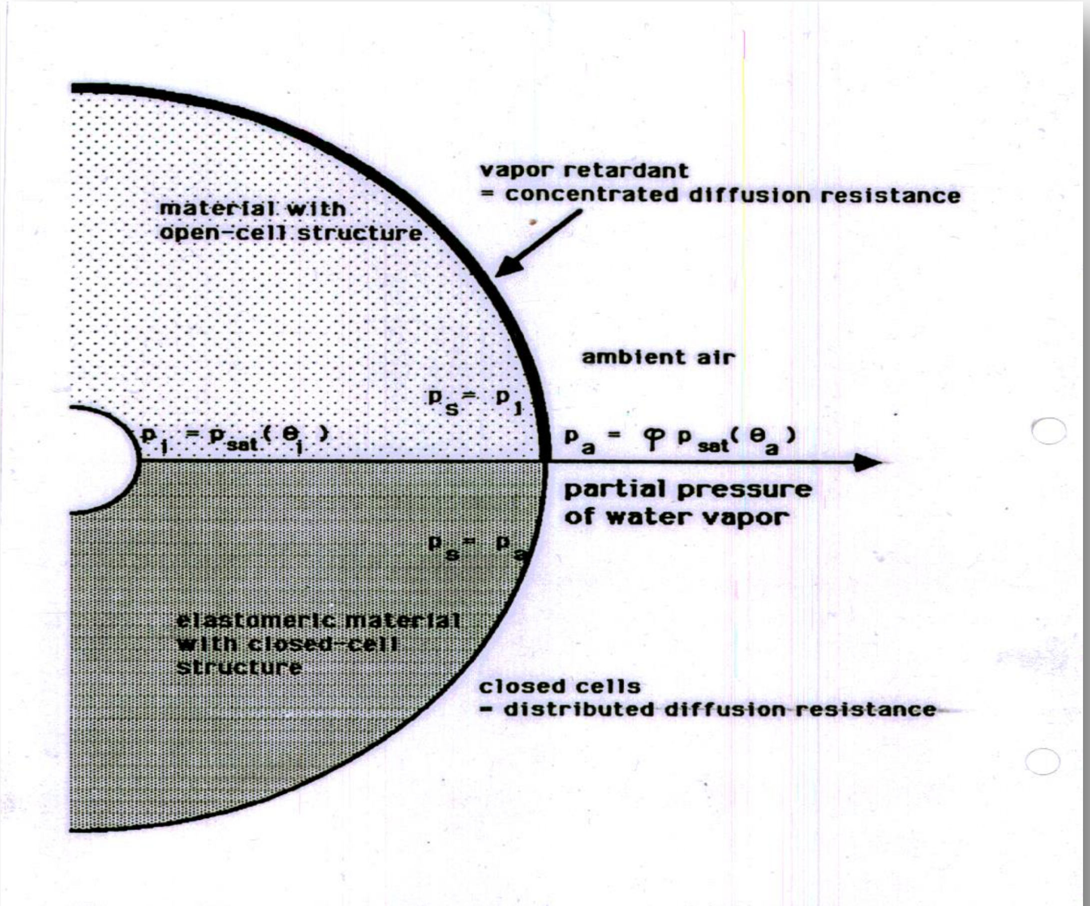


Figure 3: Resistance to Water Vapor Diffusion

THE WATER VAPOUR DIFFUSION RESISTANCE FACTOR (µ)

"It affects long term behavior of insulation. Higher the 'µ' value better the long term efficiency insulation"

"NBC 2016 Part 8 – Building Services – HVAC Item No. 7.2.7.2.a

"Insulation Material Should not be Hygroscopic"

"NBC 2016 Part 11 – Approach to Sustainability - Item No. 9.2.4.1.1.c

"Closed cell flexible elastomeric foams naturally resist ingress of water vapour, help in long term efficiency of the insulation and minimizes chances of condensation and increased heat gain over a period of time".

ASHRAE ON μ -VALUE

“The service life of the insulation depends primarily on the installed water vapour permeance of the system, comprised of the permeance of the insulation, vapour retarders on the insulation, and the sealing of the all joints, seams and penetrations….”

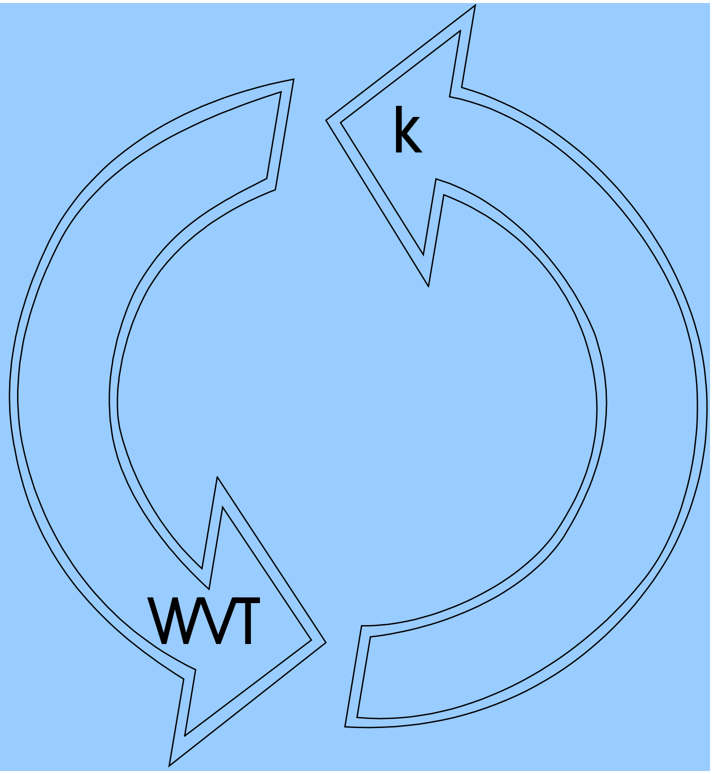
WHY VAPOUR BARRIERS ARE NOT ENOUGH?

- They are susceptible to damage during installation.
- Some foils which are used as a Vapour Barrier, are known as good vapor barriers, may have small pin holes which does not serve its purpose.
- In practical site conditions, it is very difficult to install vapour barriers properly.

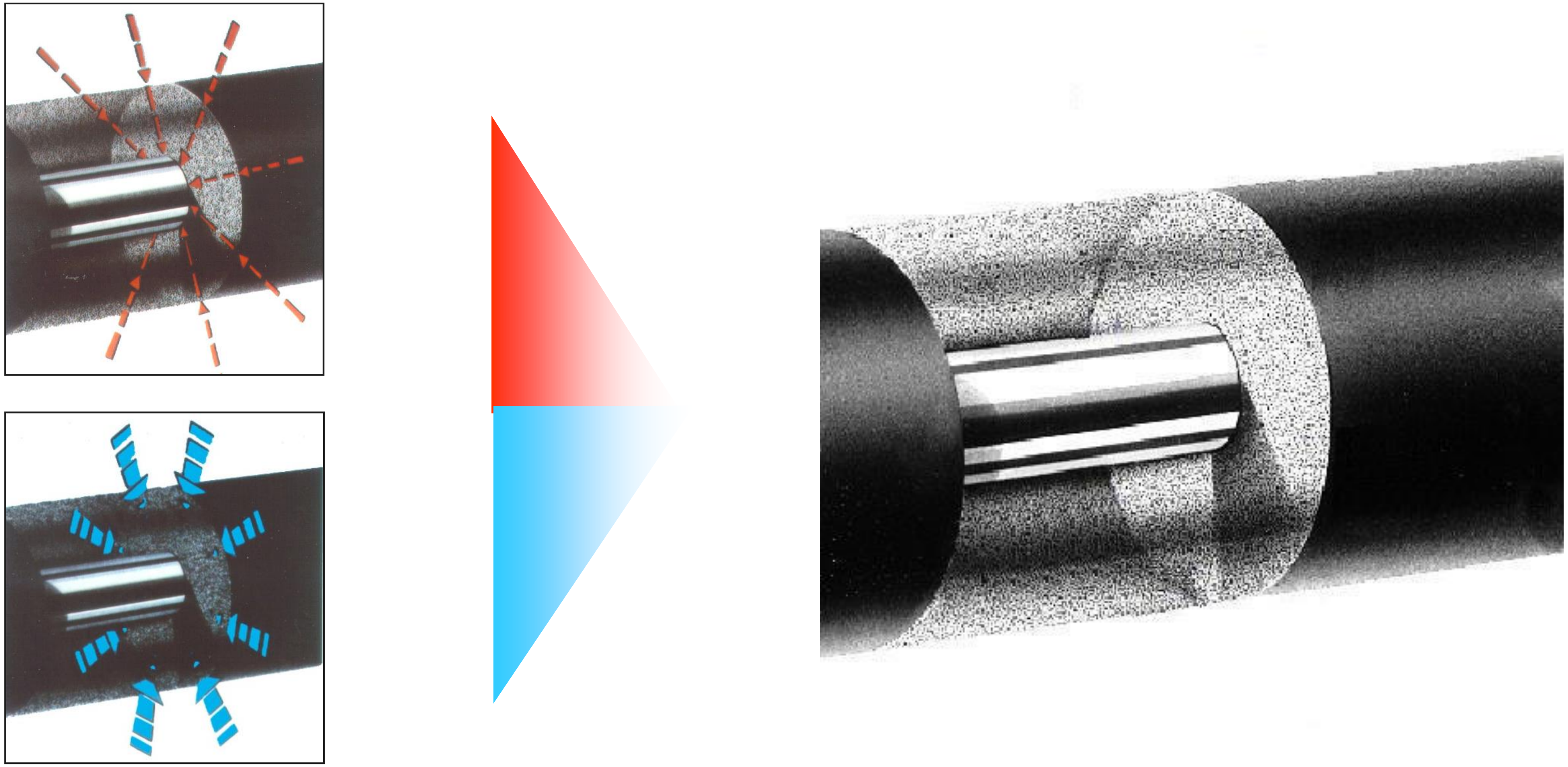
CONDUCTIVITY IS A FUNCTION OF ‘μ’

‘μ’ and Thermal Conductivity ‘λ’ both are important

When specifying or purchasing insulation for cold systems, remember that Thermal conductivity and WVT are both important to the long-term integrity of your system.



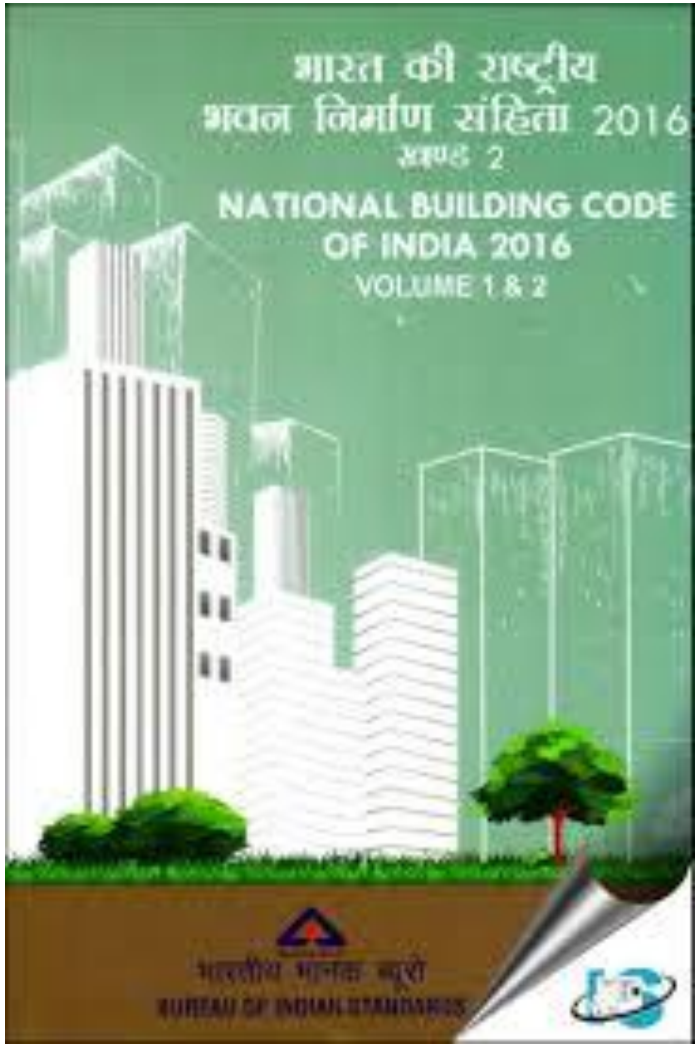
HEAT FLOW AND DIFFUSION FLOW ACT SIMULTANEOUSLY



Heat flow and diffusion flow are caused by the difference in the line and ambient temperatures

FIRE PERFORMANCE

FIRE PERFORMANCE OF INSULATION MATERIALS



"NBC 2016 Part 4 – Fire & Life Safety Item No. 2.7

"Combustible material is a material which either burns itself or adds heat to Fire"

"NBC 2016 Part 8 – Building Services - HVAC Item No. 7.2.7.2.a

"Insulation Material shall be non-combustible"

"NBC 2016 Part 8 – Building Services - HVAC Item No. 7.2.7.2.a

"Insulation Material shall not produce noxious smoke and toxic fumes"

FIRE PERFORMANCE OF NBR - FLEXIBLE FOAM INSULATION

BS 476 Part 4 – Non - Combustibility Test

BS 476 Part 7 – Test for Surface Spread of Flames – Rated as Class ‘1’

Class	**Flame Spread Distance (1.5 min)**	**Flame Spread Distance (10 min)**
Class 1	165mm	165mm
Class 2	215mm	455mm
Class 3	265mm	710mm
Class 4	Exceeding the limits for Class 3	

BS 476 Part 6 – Test for Fire Propagation – **Rated as Class ‘0’.** (Class 1 is must to perform this test).
Result in the form of Initial Index ≤ 6 and
Total Index ≤ 12.

FIRE PERFORMANCE OF ARMAFLEX INSULATION

UL 94 – Fire Test for Horizontal Burning and Vertical Burning.

BS 6853:1999 – Tested for Smoke Toxicity – R Value = 0.54

FM Approved – Factory Mutuals, U.S.A.

Practical Behavior – Self Extinguishing in Nature. Does not Drip when burning.

HEALTH HAZARDS

HEALTH HAZARD IN RELATION TO INSULATION MATERIAL USED

"NBC 2016 Part 8 – Building Services – HVAC Item No. 7.2.7.2.c

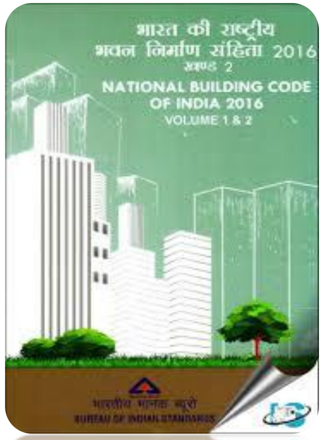
"Material should not cause a known hazard to health during application, while in use or on removal, either from particulate matter or from toxic fumes"

Flexible Elastomeric Nitrile Rubber Foams are closed cell non-fibrous materials and do not cause any health hazard. They are dust free and fiber free. Non-Carcinogen.

No risk of erosion – Tested for Air Erosion Test for 10,000 fpm Air velocities as per ASTM C – 1071-05 for FEFs used as Duct Liner

ANTIMICROBIAL AND ANTIFUNGAL BEHAVIOUR

ANTIMICROBIAL & ANTIFUNGAL PROPERTIES OF INSULATION MATERIAL USED



“NBC 2016 Part 8 – Building Services – HVAC Item No. 7.2.7.2.a

“Insulation Materials and their finishes should inherently prohibit rotting, mould and fungal growth, attack by vermin.

NBR based FEFS do have products with in-built antimicrobial and antifungal properties.

Tested as per DIN EN ISO 846 Method A for Fungal Growth
Tested as per DIN EN ISO 846 Method C for Bacterial Growth

Other Generics normally have antimicrobial and antifungal coatings which get washed off with time.

MICROBIAL GROWTH STUDY ON FIBRE GLASS

MICROBIAL GROWTH STUDY ON FEFs & FIBRE GLASS

No Microbial Growth on FEFs

Very High Microbial Growth on Fiberglass

ENVIRONMENT FRIENDLY

ENVIRONMENT FRIENDLY INSULATION

Regulation of Hazardous Substances (ROHS) as below

- **ROHS Compliant as per Directive 2011/65/EU Annexure – 2**
- **Zero ODP and GWP as per regulation EC 842/2006**
- **CFC / HCFC Free as per US EPA 5021A-2003**

NBR based FEFS comply to these standards

SELECTION OF INSULATION THICKNESS

Weather Conditions

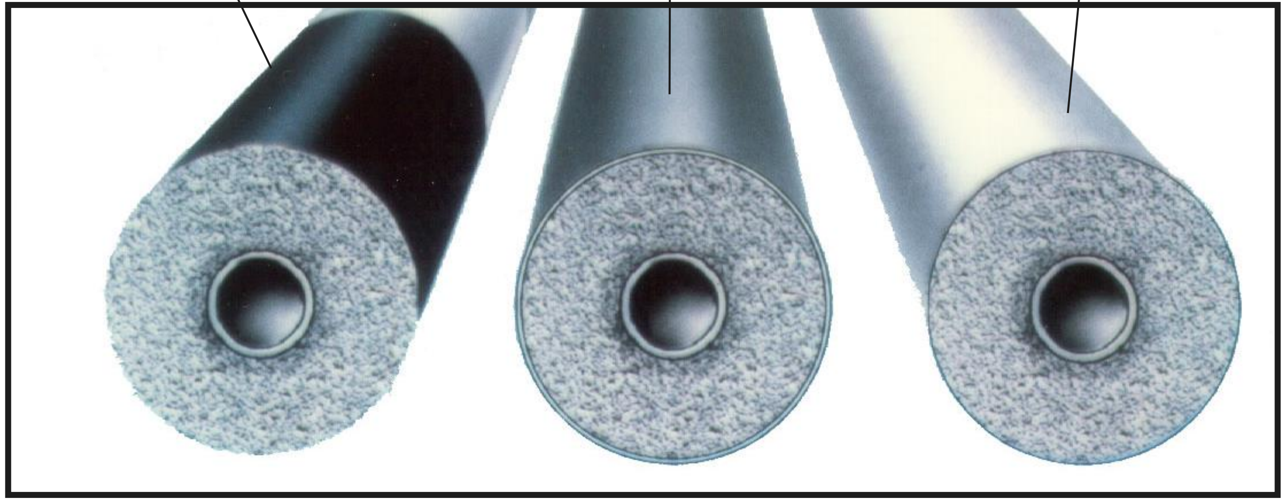
- Summer
- Monsoon
- Winters

SELECTION OF INSULATION THICKNESS

Armaflex® unpainted

With GI jacketing

With aluminum foil



Surface Emissivity ε ≈ **0.93** ≈ **0.28** ≈ **0.05**

SELECTION OF INSULATION THICKNESS

- ISO 12241 – Standard for Thickness Calculation for Thermal Insulation

$$C' = \frac{2\lambda}{h_{se}} \left(\frac{[\theta_{im} - \theta_a]}{[\theta_{se} - \theta_a]} - 1 \right)$$

Relative Humidity (ϕ)

Ambient Temperature (θa)

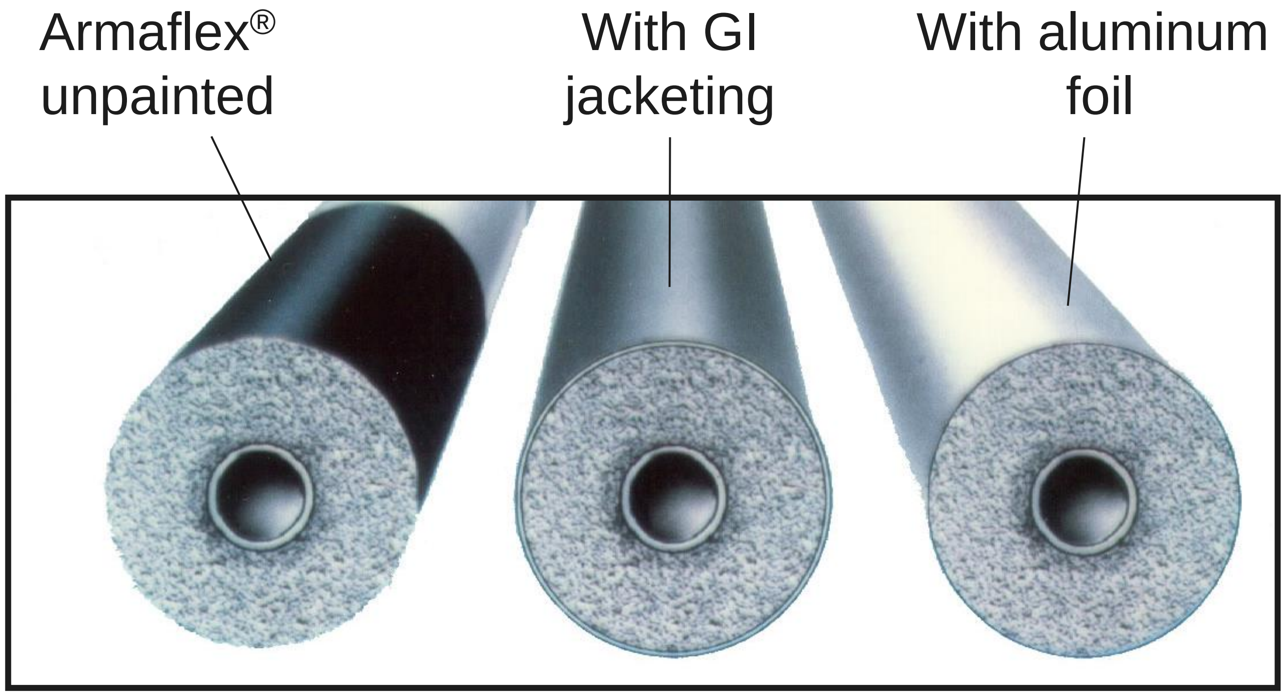
Line Temperature (θim)

h_{se} – External Surface Coefficient of Heat Transfer)

$(\theta_d - \theta_a) =$	$(\theta_{se} - \theta_a) =$	-2.7	

From Table 4 Page No. 20 of ISO 12241

SURFACE EMISSIVITY & CONDENSATION CONTROL



Surface Emissivity ε	≈ **0.93**	≈ **0.28**	≈ **0.05**

VALUES OF SURFACE COEFFICIENT

$\approx 9 \ \frac{W}{m^2 \cdot K}$

$\approx 7 \ \frac{W}{m^2 \cdot K}$

$\approx 5 \ \frac{W}{m^2 \cdot K}$

VALUES OF SURFACE COEFFICIENT

$$\approx 9 \; \frac{W}{m^2 \cdot K}$$

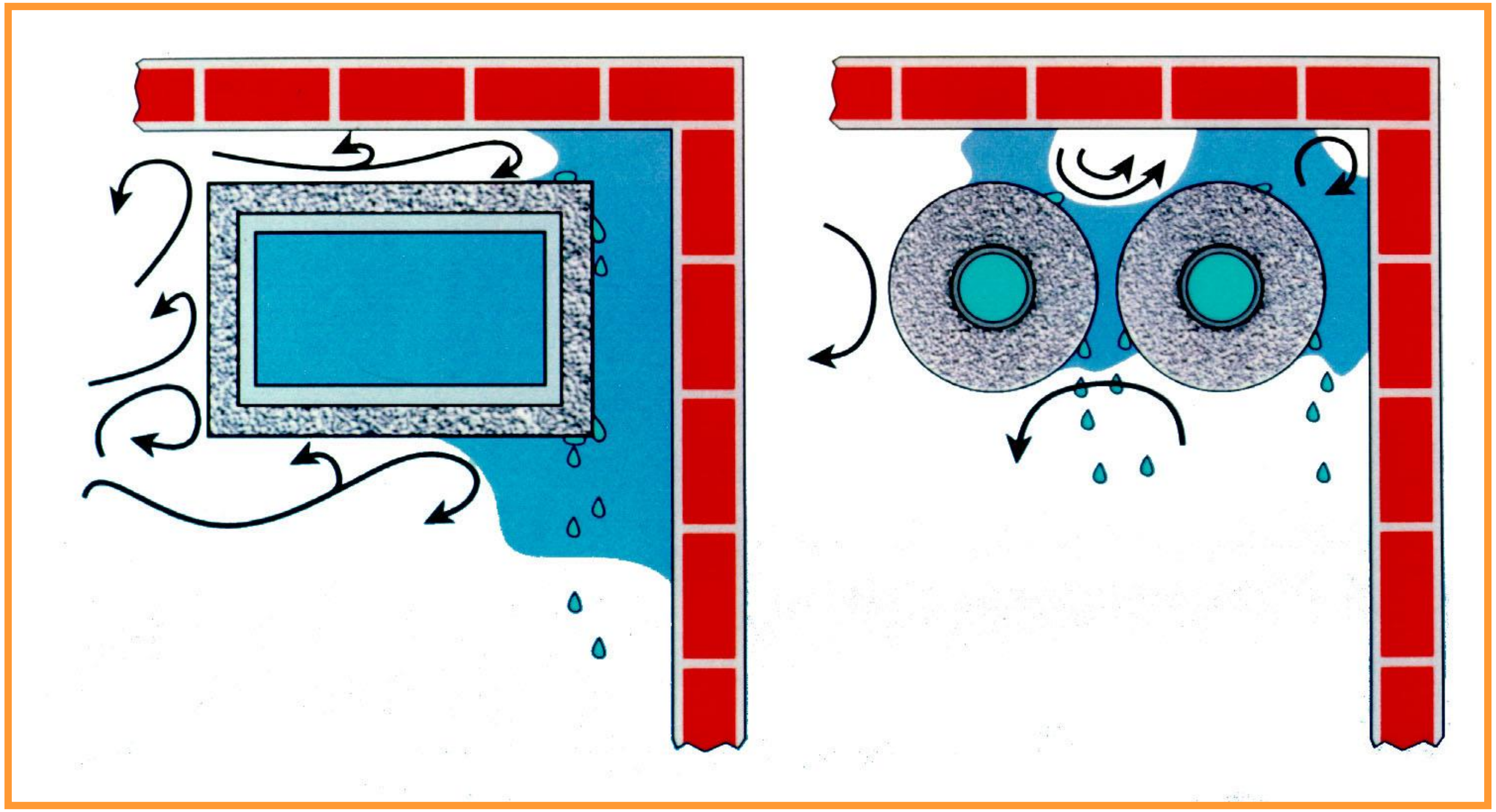
$$\approx 7 \; \frac{W}{m^2 \cdot K}$$

$$\approx 5 \; \frac{W}{m^2 \cdot K}$$

EFFECT OF SURFACE COEFFICIENT ON INSULATION THICKNESS

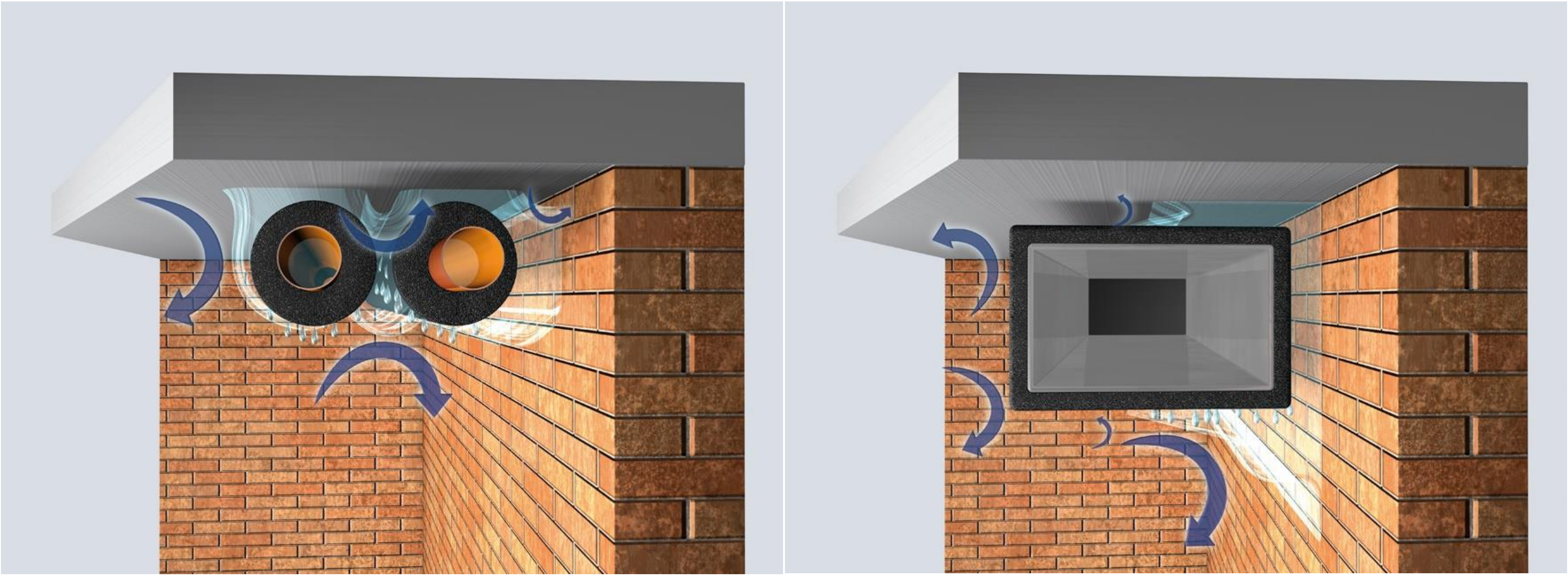
cladding	without cladding or insulation painted	steel cladding	aluminium cladding	static area
surface coefficient value [W/m^2 K]	9	7	5	3
insulation thickness s =	s_o	1,5 * s_o	1,9 * s_o	3,0 * s_o

Stationary areas affecting the convective surface coefficient

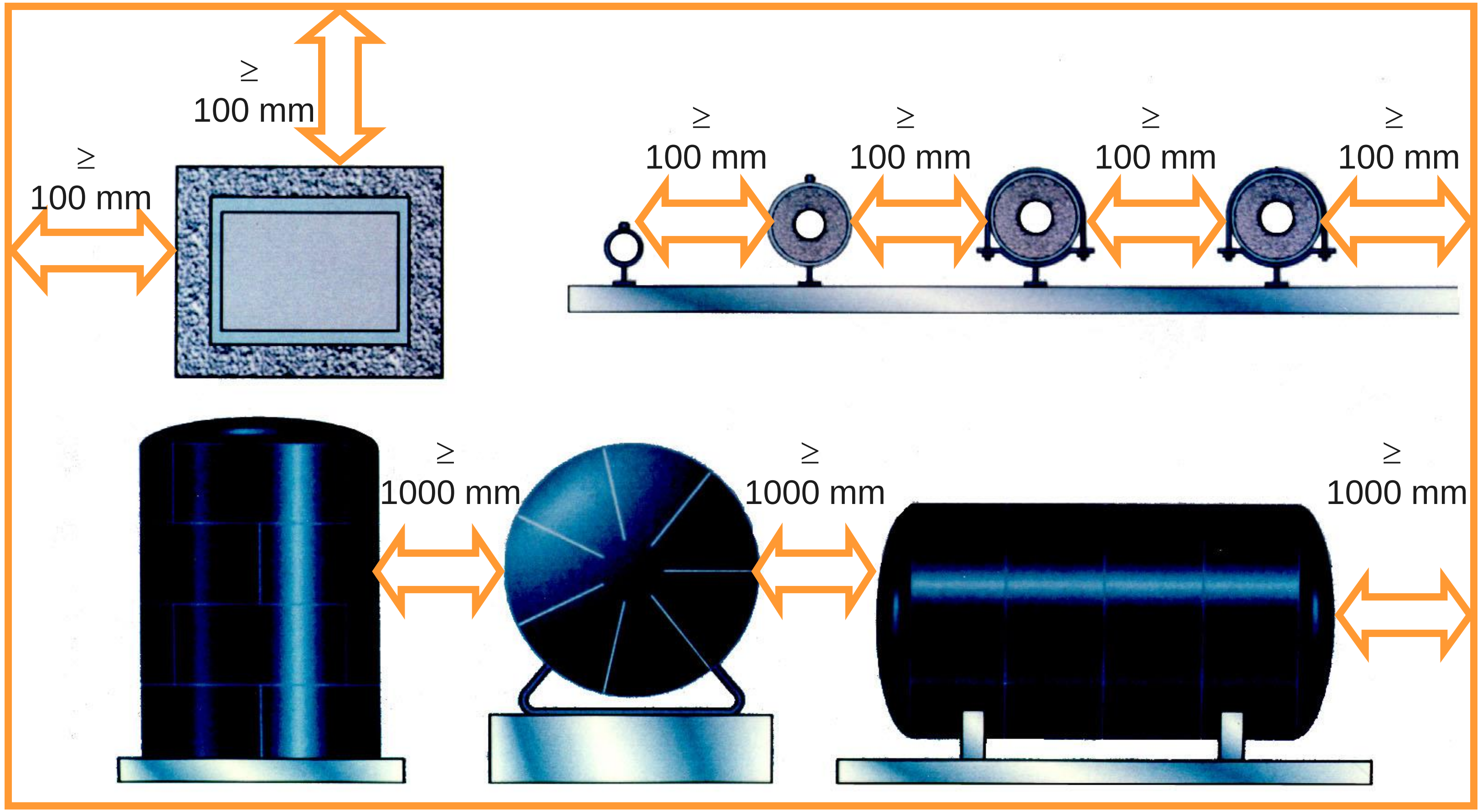


Stagnant air increases the risk of condensation!

Lack of free air circulation (convection)!



RECOMMENDED DISTANCES BETWEEN INSULATED OBJECTS AND ADJACENT STRUCTURE



DIN 4140 – Recommend minimum distance
DIN 4140 – Insulation work on industrial installations and building equipment – Execution of thermal and cold insulation

THANK YOU!